RESEARCH ARTICLE

A Study on Certain Mechanical Properties of Aluminum 7075 Reinforced with Silicon and Boron Carbide

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ABSTRACT: Composites are heterogeneous in nature which is created by the combination of two or more components with fillers or reinforcing fibers and a compactable matrix. Aluminium composites are prepared by dispersing a reinforcing material into a matrix material. Experimental study on the tribological behavior of Al-7075 alloy reinforced with boron carbide (B_4C) and silicon carbide (SiC) is conducted. Reinforcements selected have higher hardness compared to other ceramic materials. The specimens were produced with different compositions comprising SiC (3%, 6%, 9% wt %) and B_4C 5wt% in all combinations. Microstructure examinations revealed that there was uniform distribution of reinforcement material into matrix. After carrying out experiments it was found that hardness increases from 93.33 for unreinforced aluminium 7075 to 125.4 for composite combination of Al7075 + 9% SiC + 5%B_4C. Compressive strength have increased from 577.3 MN for unreinforced aluminium 7075 to 622.8 MN for composite combination of Al7075 + 9% SiC + 5%B_4C. After conduction of wear test it was found that there was less wear in the material which has got higher reinforcement. For unreinforced aluminium 7075 wear rate was 197.201 microns whereas for Al+ 9% SiC + 5%B_4C wear rate was negligible and it was 5.02 microns. Due to increase in hardness frictional force was increased. It has increased from 7.84 N for pure aluminium 7075 to 8.56 N for Al+ 9% SiC + 5%B_4C. Test results revealed that the increase in wt% fractions of reinforcement materials caused an increase in mechanical properties.

KEYWORDS: Aluminium 7075; boron carbide; silicon carbide

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1. INTRODUCTION

A composite is a structural material that consists of two or more constituents that are combined at macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and the one in which it is embedded is called the matrix [1]. Aluminium metal matrix composites (AMCs) are from the class of light weight high performance materials. In recent years AMCs are used in functional application including aerospace, defense and automotive sectors [2]. Benefits of using AMCs in automotive sector are less fuel consumption, less noise [2]. AMC can be used in preparation of gears [2] because fatigue behavior of aluminium composites is proven to be better due to low crack propagation rates compared to their unreinforced counterpart. Aluminium mixed with silicon carbide particle displayed increased fatigue endurance [3]. It is possible to process AMC having wear resistance equivalent or better than that of grey cast iron [2]. For processing AMC stir casting is the best and economical process [4, 5]. Another greater advantage of using stir casting process is that distribution of reinforcement in matrix material will be carried out uniformly [6]. This is the basic requirement in preparation of composite materials in achieving higher mechanical properties uniformly throughout all sectional area of the composite material. While selecting matrix material in AMCs, final applications of these composite materials need to be considered. The usual matrix materials in AMCs are aluminium 6061, 7075 etc. When aluminium 6061 and 7075 are compared, aluminium 7075 gives higher tensile strength and fatigue life [7]. Aluminium matrix infused with single reinforcement may show enhancement in certain characteristics with simultaneous detoriation in other critical properties, hence endorsing the synthesis of hybrid aluminium metal matrix composites with more than one filler material [8]. Presently there has been greater advancement of aluminium hybrid composites. Aluminium with boron carbide and silicon carbide as reinforcement can give higher hardness, tensile strength with negligible decrease in ductility [8]. This work is focused on preparation of Al 7075 hybrid composite reinforced

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with boron and silicon carbide. Weight percentage variations of silicon carbide are 3, 6 and 9% whereas weight percentage of boron carbide will be 5% constant. Silicon carbide percentage is increased in order to enhance mechanical properties whereas boron carbide is restricted to 5% because with increase in boron carbide percentage machining of these specimens will be a difficult task. Casting process used will be stir casting process. Mechanical properties studied will be compression strength, wear rate, hardness and microstructure analysis.

2. Experimental Details

2.1 Materials

2.1.1Matrix material

The chemical composition of the matrix material aluminium 7075 used in this investigation is given below in Table 1. The properties of aluminum 7075 are given in Table 2. The material is purchased from Fenfe metallurgical Pvt Ltd, India.

Table 1: Chemical composition of Aluminum 7075 alloy [9]

Elements	Zn	Mg	Cu	Cr	Al
% by wt	5.1	2.185	1.69	0.193	Remaining

Table 2: Properties of Aluminum 7075 alloy [10]

Properties	Values
Density g/cc	2.8
Melting point(^{o}C)	477
Tensile Strength(MPa)	572

2.1.2 Reinforcement material

Silicon carbide (SiC) is also known as carborundum. It is a semiconductor containing silicon and carbon. It occurs in nature as the extremely rare mineral. Silicon carbide is purchased from Bangalore Fine Chemicals Pvt Ltd, India. Boron Carbide (B_4C) is one among the hardest materials. It is an extremely hard boron–carbon ceramic and covalent material. It is purchased from Bangalore Fine Chemicals Pvt Ltd, India.

2.2 *Composite Preparation*

Aluminium 7075 alloy is used as matrix material. Silicon carbide Particles are dispersed in the matrix material at 3%, 6%and 9% by weight and boron carbide particles at 5% by weight. In this study silicon carbide and boron carbide particles are dispersed in Al 7075 alloy. Stir casting process is used for this. The primary processing consists of heating of Al alloy in a refractory crucible up to 750^{o}C using furnace to which preheated reinforcement (about 500^{o}C) is added and stirred well by a stirrer which rotates at 220 rpm to get uniform distribution of the reinforcement. This Al 7075 alloy containing silicon carbide and boron carbide particles is allowed to solidify in mould. Detailed procedure for the preparation of the composite is described below:

Both the base metal and the reinforcement are weighed according to the requirement. Furnace is switched ON and both the base metal and the reinforcement are heated separately to about 750^{0}C. Meanwhile the mould boxes are heated using blow torch till the mould boxes loose all the moisture. The gap between the cope and drag boxes was sealed with clay. The pre weighed and preheated reinforcement is added using the graphite spoon in the furnace simultaneously stirring the melt at 220 rpm for about 10 minutes. The reinforced molten metal is then carefully transferred to the mould boxes. The Casting is allowed to cool down and after cooling it is removed from the mould and carried away for further processing

2.3 Machining and preparation of test specimens

The solidified rods are taken out of the mould after solidification process. The ingots are cut to the required sizes to prepare samples for different tests using hacksaw.

2.3.1 Wear test specimens

The standard wear test specimen has dimensions (10*30) mm as shown in fig 1. These specimens are machined in CNC. The specimen will be in the form of a pin.

2.3.2 Hardness test specimens

The standard hardness test specimen has dimensions (20*10) mm as shown in fig1. The specimens are cut by hacksaw blade and filed by hard and smooth file on both ends to get good and even surface. One end of the specimen is cleaned by four different grid papers i.e. (120,280,400,600). When the specimen is cleaned and smooth surface is obtained specimens are taken to perform the tests.

2.3.3 Compression test specimens

The standard compression test specimen has dimensions (20*20) mm as shown in fig 1. The specimens are cut according to the dimensions required. Facing operation is carried out on both the faces of the specimen.

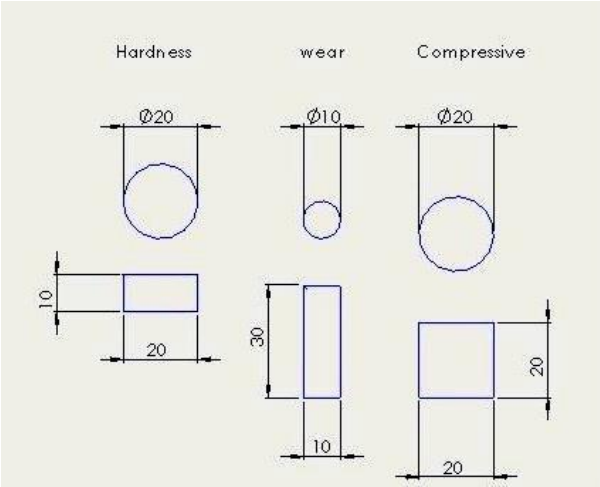

Fig 1: Test specimens dimensions (All dimensions are in mm)

3. Results and Discussions

3.1 Micro structural study

The microstructures of the specimens are studied using optical microscope. The optical microscope used for study has following specifications:

Optical System: Eye piece magnification of 50 to 2000X, 10 X eye piece with cross lines and with neutral density filter for light incidence with high resolution, contrast, and clear image camera attachment is used to view distribution of the particles in the composite matrix by observing and projecting the image on to a monitor.

Dilute Keller's etchant is used. Photomicrographs of all the specimens are taken to study their micro constituents and the distribution of particulates

Micro structural Analysis is the small scale structure of prepared material surface revealed by microscope. The specimens used for the examination are shown in figure 2. The microstructures of the composites at 40X magnifications are shown in figure 3, 4, 5.

Fig 2: Microstructure specimens

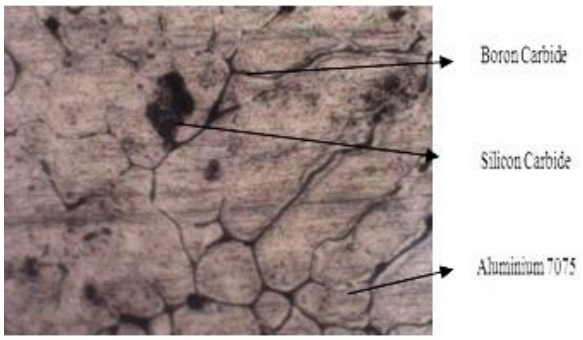

Fig 3: 40 X magnification of Al 7075 + 3% SiC + 5% B_4C

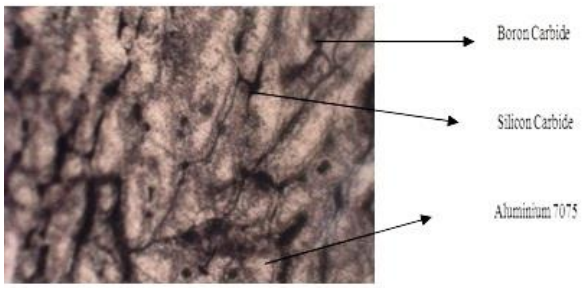

Fig 4:40 X magnification of Al 7075 + 6% SiC + 5% B_4C

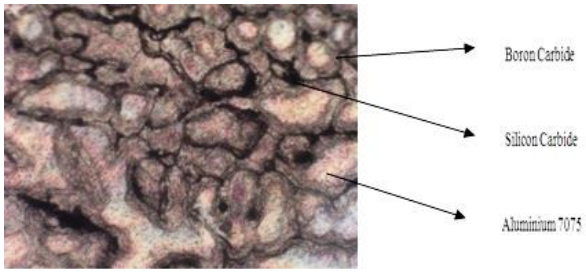

Fig 5:40 X magnification of Al 7075 + 9% SiC + 5% B_4C

The above figure reveals the microstructure of aluminium 7075 composite reinforced with silicon carbide and boron carbide. Images are obtained from electron microscope viewed below 40X magnification. The dark black network like structure indicates silicon carbide, the light black network like structure indicates boron carbide, and the white surface indicates aluminium 7075. By analysing above figures it is found that there is uniform distribution of reinforcement particles.

3.2 Hardness Test

Hardness is the Resistance of material to Deformation to any externally applied force or load.

Figure 6 shows the hardness test specimens used for conducting experiment.

Fig 6: Hardness test specimen

The formula to calculate the Vickers hardness number is VHN= $(1.854 * P)/D^2$
Where,
P= Load applied in kgf
D= $(D_1 + D_2)/2$
D_1 and D_2 are the diagonal lengths of the indent.

Table 3: Hardness Test Results

Composite Samples	Load (Kgf)	Diameter		Hardness (VHN)
		D_1(mm)	D_2(mm)	
Unreinforced Aluminium 7075	10	1)0.414 2)0.503	1)0.426 2)0.505	93.33
AL 7075 + 3%SiC + 5% B_4C	10	1)0.419 2)0.427	1)0.430 2)0.438	101.0
Al 7075 + 6%SiC + 5% B_4C	10	1)0.384 2)0.397	1)0.376 2)0.395	116.66
Al 7075 + 9%SiC + 5% B_4C	10	1)0.548 2)0.470	1)0.432 2)0.415	125.40

The above table and figure shows that the incorporation of silicon carbide and boron carbide particles in aluminium matrix causes reasonable increase in hardness, for unreinforced aluminium hardness was 93.33 whereas for aluminium reinforced with 9 wt% SiC and 5 wt% B_4C was increased up to 125.40. The strengthening of the composite can be due to dispersion strengthening as well as due to particle reinforcement. Thus, silicon carbide and boron carbide as filler in aluminium casting reduces cost and increase hardness which are needed in various industries like automotive etc.

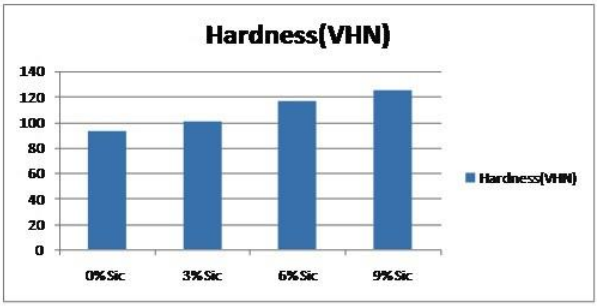

Fig 7: Hardness Vs Hybrid Reinforcement Wt %

3.3 Compression Test

Compressive strength is the capacity of the material to resist loads tending to reduce size.

Unreinforced Al 7075 **Al 7075 + SiC 3% +B_4C 5%**

Al 7075 + SiC 6% +B_4C 5% **Al 7075 + SiC 9% +B_4C 5%**

Fig 8: compression test specimens after compression test

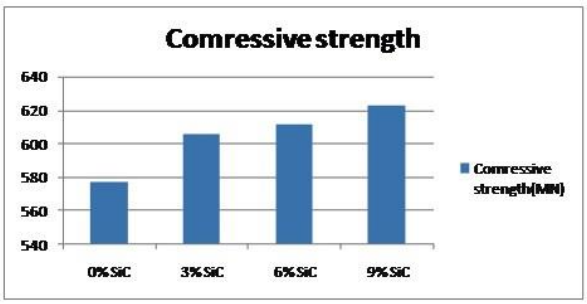

Fig 9 Compressive strength Vs Hybrid Reinforcement Wt %

Table 4: Compression Test Results

Composition	Maximum Diameter (mm)	Maximum Load (KN)	Compressive Strength (MN)
Unreinforced Al 7075	20.08	184.740	577.3
Al 7075 + SiC 3% +B_4C 5%	20.08	193.890	605.9
Al 7075 + SiC 6% +B_4C 5%	20.08	195.630	611.3
Al 7075 + SiC 9% +B_4C 5%	20.08	199.620	622.8

Formula to calculate the compressive strength, F_c=P/A
Where, P=maximum load in (KN).
A=Area of the specimen calculated by A= (3.14*D^2) /4,
D=Diameter of the specimen

Table 5: Wear Test Results at Load 20N

Composition	Load (N)	Wear (microns)	Frictional force (N)
Unreinforced Al 7075	20	197.201	7.84
Al 7075 + SiC 3% + B_4C 5%	20	48.957	8.024
Al 7075 + SiC 6% + B_4C 5%	20	18.856	8.093
Al 7075 + SiC 9% + B_4C 5%	20	5.02	8.56

The above table and figure shows that the incorporation of silicon carbide and boron carbide particles in aluminium matrix causes reasonable increase in compressive strength. For unreinforced aluminium compressive strength was 577.3 MN whereas for aluminium reinforced with 9 wt% silicon carbide and 5 wt% boron carbide was increased up to 622.8 MN .The specimen bulges when load reaches certain point. If still load is being applied then Crack initiation takes place and specimen breaks down.

3.4 Wear Behavior of composite specimens

Wear is the gradual removal or deformation of material at solid surfaces. Frictional force is the force that resists the relative motion of surfaces or materials against each other.

The wear test was carried out using Pin-On Disc wear tester with disc speed from 0-800 rpm, load 0-100 N, and frictional force 0-100 N. The disc is alloyed steel with HRB 120 having a diameter of 120 mm and thickness 10 mm. The surface of the pin is cleaned with acetone before the test. Wear test is carried for load 20N. Speed maintained is 1000rpm and time 600 sec. As shown in table 5 wear rates gradually decrease with the increase in percentage of reinforcement materials at 20 N Load. The wear of pure aluminium alloy is 197.201 microns and for silicon carbide 9% + boron carbide 5% wear of the material has decreased to 5.02 microns. It is due to addition of silicon carbide and boron carbide particles which adds to hardness of the material. Frictional force is inversely proportional to wear rate. Frictional force is increasing thereby decreasing Wear.

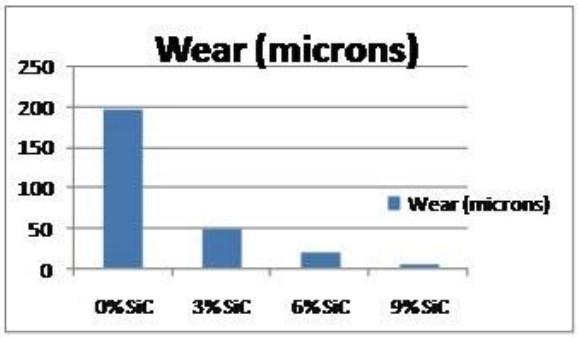

Fig 10: Wear Vs Hybrid Reinforcement Wt % for 20N Load

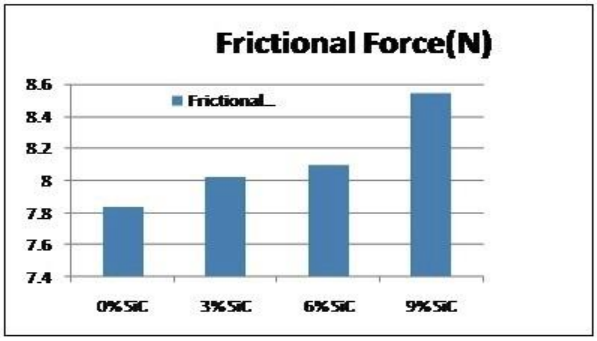

Fig 11: Frictional Force Vs Hybrid Reinforcement Wt % for 20N Load

4. CONCLUSION

Successful fabrication of Al 7075 alloy/ silicon carbide - boron carbide particulate composite has been made under the varying additions (3%, 6%. 9%) of silicon carbide and constant boron carbide (5%) in weight fractions. The micro structural study reveals that the silicon carbide –boron carbide particulates are uniformly distributed in the composites and no interfacial reactions are seen under 40X magnifications. The dispersion of silicon carbide - boron carbide particles in to Al-7075 alloy melt significantly increases hardness values. The hardness has increased with the additions of silicon carbide. For unreinforced aluminium hardness was 93.33 whereas for aluminium reinforced with 9 wt% silicon carbide and 5 wt% boron carbide it was increased up to 125.40. The compressive strength was increased reasonably for aluminium reinforced with 9 wt% silicon carbide and 5 wt% boron carbide .For unreinforced aluminium compressive strength was 577.3 MN whereas for aluminium reinforced with 9 wt% silicon carbide and 5 wt% boron carbide it was increased up to 622.8 MN. The wear rates of the composites have decreased with increase in silicon carbide percentage. Higher wear resistance of the composite was obtained for 9 wt% addition of silicon carbide and 5% addition of boron carbide. Frictional force has decreased with increased percentage of reinforcement. For 20N the lowest frictional force was obtained at 9% wt silicon carbide and 5% wt boron carbide.

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